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PHYSICS.—*The relation between color temperature, apparent temperature, true temperature, and monochromatic emissivity of radiating materials.* PAUL D. FOOTE, Bureau of Standards.

In an earlier note[1] the relation between color temperature and true temperature was discussed. The present paper interrelates the color temperature, apparent temperature, true temperature, and monochromatic emissivity coefficient of a radiating material. A new method of determining the temperature coefficient of monochromatic emissivity is also considered.

Most metals are supposed to have practically zero temperature coefficient of monochromatic emissivity in the visible spectrum, a region of resonance where the well known Maxwell relations for emission coefficient do not apply. This supposition is not thoroughly warranted by experimental data, since the accuracy of many of the data is not sufficient to detect a 10 per cent change in emissivity over a temperature range of several hundred degrees. For some metals, moreoever, a small temperature coefficient of monochromatic emissivity has been observed. The following empirical equation may represent the emissivity for wave lengths in the visible spectrum and a moderate temperature range where A', c_2, p and q are constants, A the emissivity coefficient, T the absolute true temperature, and λ the wave length in microns.

[1] FOOTE and FAIRCHILD, J. Wash. Acad. Sci. **6**: 193–197. 1916. In this paper the following corrections were overlooked in the manuscript. Eq. (3), change $+\frac{c_2}{\lambda}$ to $-\frac{c_2}{\lambda}$, page 195, Eq (5) and lines 10 and 14, change $+p$ to $-p$.

$$A = A' e^{\frac{cp}{\lambda}} e^{\frac{q}{T}} \tag{1}$$

By proper choice of A', p, and q, the above equation can be adjusted to fit almost any curve of emissivity which is likely to be found experimentally. A type of dispersion of emissivity which it can not represent is that in which the emissivity possesses a very decided maximum in the middle of the visible spectrum. There is no experimental evidence of such a form of emissivity as a function of the wave length for metals, possibly excepting gold and copper. Over the small range of wave lengths comprised by the visible spectrum the emissivity of most metals is, within experimental observations, either increasing or decreasing linearly or exponentially with the wave length. All such variations are accounted for by adjusting the constant p. If the emissivity is constant with wave length, as in the case of a gray body, $p = 0$. Similarly, all probable variations in the emissivity with temperature over a reasonable temperature range are accounted for by adjusting the constant q. The only serious restriction to equation (1) is that it assumes all wave lengths of the visible spectrum have the same temperature coefficient of emissivity. This assumption is probably practically correct—there is no satisfactory experimental evidence bearing directly upon this point.

If a material having an emissivity coefficient given by equation (1) is compared spectrophotometrically with a black body at various temperatures, and the logarithmic isochromatics are plotted for various wave lengths (viz., logarithm of the ratio, at a definite wave length, of the intensity of radiation of the non-black body at true absolute temperature T to that of a black body at absolute temperature θ, versus $1/\theta$) these isochromatics will show the following form. (Natural logarithms throughout.)

$$\log \frac{J_2}{J_1} - \left(\log A' + \frac{q}{T}\right) = \frac{c_2}{\lambda}\left\{\frac{1}{\theta} - \left(\frac{1}{T} - p\right)\right\} \tag{2}$$

where

$$J_1 = c_1 \lambda^{-5} e^{-\frac{c_2}{\lambda\theta}} \quad \text{for black body}$$

$$J_2 = c_1 A \lambda^{-5} e^{-\frac{c_2}{\lambda T}} \quad \text{for non-black body}$$

Equation (2) represents a family of straight lines of variable parameter $\frac{c_2}{\lambda}$ intersecting at $\log A' + \frac{q}{T}$ and $\frac{1}{T} - p$. At the point of intersection the ratio of the intensity of the non-black body to the intensity of the black body is the same for every color. This by definition is a "color match" and the temperature of the black body when the condition of color match exists is the "color temperature" of the non-black body. Denote the color temperature by T', then

$$\frac{1}{T'} = \frac{1}{T} - p \tag{3}$$

If S denotes the apparent temperature of the non-black material for a wave length λ, equation (4) follows immediately from Wien's law,

$$\frac{1}{S} + \frac{\lambda \log A}{c_2} = \frac{1}{T} \tag{4}$$

and from equations (1), (3) and (4)

$$\frac{1}{S} - \frac{1}{T'} = -\frac{\lambda q}{c_2}\left(\frac{\log A'}{q} + p + \frac{1}{T'}\right) \tag{5}$$

which is a straight line of slope $-\frac{\lambda q}{C_2}$ when $\left(\frac{1}{S} - \frac{1}{T'}\right)$ is plotted against $\frac{1}{T'}$. The apparent temperature S and the color temperature T', easily measured quantities, may therefore be used to determine the constant q, and thus give the temperature coefficient of monochromatic emissivity.

Color temperature of carbon. From the work of Elisabeth Benedict[2] and also from some unpublished work of the writer it appears that the logarithmic isochromatics for a carbon lamp

[2] Ann. d. Physik, **47**: 641. 1915.

intersect at a point for any temperature of the lamp. That is, a perfect color match against a black body is possible at all temperatures. Hyde, Cady, and Forsythe[3] have published a table of color temperature versus apparent temperature ($\lambda = 0.665\mu$) for an untreated carbon filament lamp. If $\left(\frac{1}{S} - \frac{1}{T'}\right)$ is plotted against $\frac{1}{T'}$ using their observations, the relation is found to be linear within observational errors, in accordance with equation (5). From the slope of the line, q is found to be $+462$. Putting this value of q in equation (1) the monochromatic emissivity is seen to decrease with increasing temperature as follows.

TABLE I

TEMPERATURE ABSOLUTE	RELATIVE MONOCHROMATIC EMISSIVITY
1500	1.00
2000	0.92
2400	0.89

Mendenhall and Forsythe[4] experimentally found the emissivity at 1300 and 2300° absolute to be 0.86 and 0.79 respectively. This is in qualitative agreement with the above table.

Color temperature of tungsten. A more interesting verification of the correctness of the above equations is obtained by a consideration of Hyde, Cady, and Forsythe's[5] data on tungsten. In this paper a table is given of the observed color temperatures, true temperatures, and apparent temperatures ($\lambda = 0.665\mu$) for a tungsten lamp. From the values of the apparent temperature and true temperature the emissivity for $\lambda = 0.665\mu$ may be computed according to equation (4). Taking the value of $c_2 = 14350$ it was found that $e^{\frac{322}{T}}$ represents the temperature coefficient exactly. The coefficient p of equation (1) was found to be $+0.0000104$ and the general equation for emissivity of tungsten is as follows.

[3] J. Frank. Inst. **181**: 420. 1916.
[4] Astrophys. J. **37**: 389. 1913.
[5] Loc. cit. p. 419. Also WORTHING, idem, p. 417.

(6) $$A = 0.304\, e^{\frac{0.1492}{\lambda}}\, e^{\frac{322}{T}}$$

Where λ = wave length in microns and T = true absolute temperature. The relation between the color temperature and true temperature follows from equation (3) viz. $1/T' = 1/T - 0.0000104$. The agreement between the computed and observed values illustrated in the following table is surprisingly good, and proves at once that the above theoretical relations have a sound physical significance.

TABLE II

OBSERVED VALUES				COMPUTED VALUES		
$S_{0.665\mu}$	T	T′	$A_{0.665\mu}$	$A \propto e^{\frac{322}{T}}$	T′	$T'_{obs} - T'_{comp}$
1627	1729	1763	0.458	0.458	1761	+2
1753	1875	1917	0.448	0.451	1912	+5
1840	1976	2025	0.446	0.447	2017	+8
1909	2056	2109	0.448	0.445	2101	+8
1967	2125	2179	0.442	0.442	2173	+6
2017	2184	2237	0.441	0.440	2235	+2
2062	2238	2290	0.439	0.439	2291	−1
2102	2286	2338	0.438	0.438	2342	−4
2113	2299	2350	0.438	0.437	2355	−5
2140	2332	2383	0.436	0.436	2390	−7
2174	2373	2425	0.435	0.435	2433	−8
Average deviation				±0.0008		±5°

As seen from columns 6 and 7, the color temperature, computed by equation (3) where $p = 0.0000104$, agrees far within experimental errors with the observed color temperature, the difference between the computed and observed values showing an average deviation of only 5°.

Using equation (6) one can predict what the emissivity at any wave length will be. Table III gives the emissivity of tungsten for several wave lengths. Whether equation (6), obtained indirectly from the color temperatures, can be used as far out as $\lambda = 0.4\mu$ is of course questionable. It is not likely however that the values are in great error.

TABLE III

T	EMISSIVITY (c_2 = 14350)				
	0.7 μ	0.665 μ	0.6 μ	0.5 μ	0.4 μ
1700	0.455	0.460	0.471	0.50	0.53
1800	0.450	0.455	0.466	0.49	0.53
1900	0.446	0.451	0.462	0.49	0.52
2000	0.442	0.447	0.458	0.48	0.52
2100	0.439	0.444	0.454	0.48	0.51
2200	0.436	0.440	0.451	0.47	0.51
2300	0.433	0.438	0.448	0.47	0.51
2400	0.431	0.435	0.446	0.47	0.50

Color temperature of platinum. Koenigsberger has determined[6] the emissivity for various wave lengths in the visible spectrum for platinum at room temperature. If the logarithm of the emissivity is plotted against $1/\lambda$ the slope of the straight line is c_2p, whence p of equation (1) is directly determined. This computation gives $p = 0.0000287$. Waidner and Burgess[7] determined the emissivity of platinum at its melting point (assuming melting point = 1755°C.) for three different wave lengths. Their values give $p = 0.0000185$. It is quite possible that this latter value of p is too low because of the difficulty in obtaining accurate measurements of emissivity at high temperatures. If both values of p are correct platinum must have a temperature coefficient of emissivity and the temperature coefficient must be a function of the wave length. The following table shows the relation between the color temperature and the true temperature of platinum, based on both values of p.

TABLE IV

$p = 0.0000287$			$p = 0.0000185$	
T	T′	T′ − T	T′	T′ − T
1000	1030	30	1019	19
1500	1567	67	1543	43
2000	2122	122	2077	77

[6] Ann. d. Physik, **43**: 1205–22.
[7] Bur. Stds. Sci. Paper No. 11, p. 244. 1905.

The interesting point is that the color temperature of platinum at the melting point must be 80° and possibly 120° higher than the true temperature. This is at variance with the conclusions drawn by Paterson and Dudding,[8] who claim that platinum is practically gray thus requiring that $p = 0$ and $T = T'$.

Conclusion. The various relations between color temperature, apparent temperature, and true temperature are pointed out for the first time. These relations are checked by observations of Hyde, Cady, and Forsythe on tungsten and are found to agree excellently with experiment. Color temperatures open a new field in the subject of optical pyrometry which is certain to prove highly interesting. Color temperature may be measured by the spectrophotometer using the method of logarithmic isochromatics, or by an ordinary photometer if the observer is skilled in color matching. A still better means perhaps of studying the color temperatures of various materials is by use of a suitable form of colorimeter. Measurement of the dominant hue of a black body and of metals at various temperatures is a field of investigation as yet untouched.

PHYSICS.—*Luminosity and temperature of metals.* PAUL D. FOOTE, Bureau of Standards.

Recently Mr. Fairchild and the writer published a paper on the relation between the luminosity and temperature of a black body.[1] In the present note this work is extended to apply to the case of radiation from metals, and from oxides for which the emissivity coefficient can be represented by equation (4) below. Luminosity of a black body is defined as the integral from 0 to ∞ in respect to $d\lambda$ of the product of visibility (V) and energy (J) of the radiating source thus:

$$(1) \qquad L = \int_0^\infty VJ\,d\lambda$$

where $V = f(\lambda)$ and $J = c_1 \lambda^{-5} e^{-\frac{c_2}{\lambda\theta}}$ = Wien's law.

[8] Proc. Phys. Soc. London, **27**: 253. 1915.

[1] Bureau of Standards Sci. Paper No. 270. 1916.

The integral of equation (1) obtained graphically using the data of Ives, Nutting, and Hyde and Forsythe for visibility was found to have the following form.

$$L = P\left(\frac{\theta + B}{\theta + C}\right)^D \tag{2}$$

where, for $c_2 = 14450$

$$B = -105.92$$
$$C = +265.46$$
$$D = +72.166$$

The luminosity of a non-black body, such as a metal, is defined by equation (3) where A is the emissivity coefficient of the non-black material.

$$L' = \int_0^\infty AVJd\lambda \tag{3}$$

The writer has shown[2] that for most metals the emissivity coefficient can be accurately represented by equation (4) where A', p, and q, are constants, λ the wave length in microns, θ the true absolute temperature.

$$A = A' e^{\frac{p c_2}{\lambda}} e^{\frac{q}{\theta}} \tag{4}$$

If equation (4) is substituted in (3) one obtains the following:

$$L' = A' e^{\frac{q}{\theta}} \int_0^\infty c_1 \lambda^{-5} e^{-\frac{c_2}{\lambda\theta}} e^{\frac{p c_2}{\lambda}} V(\lambda)\, d\lambda \tag{5}$$

(6) Let $$\frac{1}{\theta'} = \frac{1}{\theta} - p$$

(7) then $$L' = A' e^{\frac{q}{\theta}} \int_0^\infty c_1 \lambda^{-5} e^{-\frac{c_2}{\lambda\theta'}} V(\lambda)\, d\lambda$$

The integral in equation (7) is identical with that of (1) hence from (2):

$$L' = A' e^{\frac{q}{\theta}} P\left(\frac{\theta' + B}{\theta' + C}\right)^D \tag{8}$$

[2] This JOURNAL, **6**: 317–323. 1916.

which represents the luminosity of a non-black body at temperature θ where θ' is given by equation (6). It is well known that θ' is the color temperature[3] of the non-black body.

Application of equation (8) to the determination of the melting point of tungsten. Langmuir[4] found the luminosity of tungsten to be 6994 candles per square centimeter at its melting point. Equation (8) may be used to determine the temperature corresponding to this value of the luminosity after the constants P, A' p, and q have been evaluated. The constant P is obtained by equation (2) from the work of Hyde, Cady, and Forsythe[5] upon the brightness of a black body at various temperatures. The result of this computation is shown in the following table.

TABLE I

θ	candles/cm^2	$P \times 10^{-7}$
1700	5.3	1.94
1800	11.3	1.84
1900	24.4	1.92
2000	45.0	1.84
2100	80.0	1.80
2200	146.0	1.91
2300	248.0	1.97
2400	382.0	1.93
2500	600.0	1.98
2600	880.0	1.97

Mean $P = 1.91 \pm 0.05 \times 10^7$

The constants p and q, on the basis of Hyde, Cady, and Forsythe's[6] data for color temperature, true temperature and apparent temperature of tungsten were found[7] to have the values $p = +0.0000104$ and $q = +322$. On the basis of $c_2 = 14450$ and these data $A' = 0.303$. From equation (6) θ' is found, whence from equation (8) L', the luminosity for various values

[3] FOOTE and FAIRCHILD, J. Wash. Acad. Sci. **6**: 195. 1916. FOOTE, this JOURNAL, **6**: 317–323. 1916.

[4] Phys. Rev. **6**: 141. 1915.

[5] J. Frank. Inst. **181**: 421. 1916.

[6] J. Frank. Inst. **181**: 419. 1916. Also WORTHING, idem, p. 417.

[7] FOOTE, this JOURNAL, **6**: 317–323. 1916.

of the true temperature θ may be computed. From a curve of L' versus θ the temperature corresponding to a luminosity of 6994 candles per square centimeter is found to be 3712° absolute. If one uses Langmuir's values of the emissivity, the constants A', p, and q have the values: $A' = 0.388$, $p = +\ 0.0000079$, and $q = 0$. This gives a temperature of 3660° absolute for the melting point of tungsten.

Summary. An equation has been derived giving the relation between luminosity and temperature of a non-black body, more especially a metal. This has been applied for the computation of the melting point of tungsten from Langmuir's determinations of the luminosity of tungsten at its melting point. The value of 3712° absolute is obtained on the basis of Hyde, Cady, and Forsythe's and Worthing's measurements on the color temperature, true temperature, and apparent temperature of tungsten. If Langmuir's values for the emissivity are used, the melting point is found to be 3660° absolute. Both of these values are computed on the basis of $c_2 = 14450$ and upon Hyde, Cady, and Forsythe's values of the luminosity of a black body at various temperatures.

CRYSTALLOGRAPHY.—*Crystals and crystal forces.*[1] F. E. WRIGHT, Geophysical Laboratory.

The object of this paper is to state a problem, namely, that of the measurement of crystal forces, and to discuss briefly some of the more important phenomena which result from the action of these forces and which may possibly be of value in the solution of the general problem.

A crystal is a body whose component atoms are arranged in definite space lattices; this arrangement is probably the result of the vectorial action of interatomic forces and, as a rule, finds outward expression in the development of flat crystal faces. In this definition no reference is made to the state of cohesion of the body, whether solid or liquid; nor to its homogeneity. Ordinarily these attributes are essential and are included in the definition; but the discovery of liquid crystals by Lehmann has

[1] Read before the Geological Society of America on December 29, 1915.

rendered rigidity in a crystal a less fundamental characteristic than it was formerly supposed to be; while the common occurrence of zonal growth in natural mix-crystals has taken away some of the emphasis which used to be placed on chemical and physical homogeneity. In general, crystals are rigid and show a high degree of homogeneity and are bounded by flat faces; but the fact that these characteristics are lacking in certain individual units has an important bearing on the theory of crystal growth and crystal forces.

In crystals there is a regular periodic arrangement in space of the component atoms. All theories of crystal structure are based on this postulate which in recent years has been confirmed by the brilliant investigations, especially, of Professor W. H. Bragg and his son, W. L. Bragg, on the phenomena of diffraction and reflection of characteristic X-rays from oriented crystal plates. From this it may be inferred that the orderly arrangement of the atoms in interpenetrating space lattices is the result of the action of interatomic forces which are spacially vectorial in character. Little is known, however, of the order of magnitude of these forces and of the law of their variation with distance. The problem of measuring these forces and of ascertaining the laws describing their behavior may be treated from different viewpoints.

Development of crystal forms. The development of crystal forms as it has been stated by Victor Goldschmidt[2] in his law of complication is a remarkable expression of the action of crystal forces; this law may, in a given crystal substance, enable us to ascertain the directions of the primary poles of attraction in the crystal structure.

Crystal growth. Studies on the rate and character of crystal growth have added much to our knowledge of the individuality of a particular crystal group and also of the mechanism of crystal growth. The importance of diffusion and adsorption in crystal growth is now clearly recognized; Marc[3] and others have shown

[2] Uber Entwickelung der Kristallformen. Zeitschrift für Kristallographire, **28**: 1. 1897.

[3] Zeitschrift für Physikalische Chemie, **67**: 470. 1909; **67**: 640. 1909; **68**: 104. 1909; **73**: 685. 1910; **75**: 710. 1911; **79**: 71. 1912; **81**: 641. 1912.

that the presence, in the solution, of minute quantities of certain colloids or semicolloids may influence profoundly the rate and character of crystal growth, these colloids probably entering into the surficial adsorbed layer and changing greatly the rate at which the molecules diffuse through the adsorbed film to the growing crystal. Gibbs concluded from thermodynamical relations that, because of the vectorial character of crystals, the surface tension on different crystal faces is different and that, therefore, a difference in the solubility of these faces must exist; Curie inferred that in a growing crystal the tendency exists, by virtue of surface tensional forces, to develop in such form that the total surface energy is a minimum. Ritzel and Marc[4] concluded further that because of the differences in solubility of the different faces the tendency also exists for the less soluble forms to develop at the expense of the more soluble and that, therefore, the final crystal form represents the equilibrium adjustment between these two tendencies, namely, toward total minimum surface energy and toward faces of minimum solubility. The same relations should, of course, obtain for vapor pressures over different faces, since vapor pressure may be looked upon as solubility in a vacuum. Experimentally these relations are very difficult to test satisfactorily, partly because of the formation of etch figures. It is probable that accurate vapor pressure measurements will furnish results least open to criticism.

Field of atomic forces. The distances through which atomic and molecular forces act effectively have been shown by different methods to be of the order of magnitude of 5 $\mu\mu$. Lehmann observed that small acicular liquid crystals of ammonium oleate on precipitation from solution exert, if sufficiently close together, a mutual orienting influence; and that, finally, after having attained strict parallelism, they coalesce. Certain liquid crystals are susceptible, moreover, to the orienting influences of a magnetic field. The analogy between a magnetic field and the field of the atoms and molecules in a crystal is more significant than may appear at first sight. In modern theories on the

[4] Zeitschrift für Physikalische Chemie, **76**: 584. 1911.

constitution of matter the atom is considered to consist of an electrically positive nucleus surrounded by negative electrons. The fields surrounding the atoms in a crystal may be electromagnetic in nature.

Influence of a crystal system of forces on other systems of forces, especially light waves. Crystals exert a profound influence on transmitted light waves. The effects which are thereby produced constitute the subject matter of crystal optics, in which light waves are commonly treated from the viewpoint of the electromagnetic theory. It is known that with change in pressure or in temperature the distances between the component atoms of a crystal are changed slightly and that these slight changes induce corresponding changes in the optical constants of the crystal. Under these conditions we are dealing with two distinct systems of forces, the crystal system and the light wave system; by measuring quantitatively the differential shifts which these slight changes in the crystal system of forces produce in the light wave system of forces we obtain a relation between the differential changes in the two systems of forces; in short, a differential equation which, if we can integrate it and determine the constants in terms of absolute elastic units, will enable us to determine the form of the force-function of the crystal system and thus to obtain a measure of atomic forces. This problem is now under attack at the Geophysical Laboratory. Apparatus has either been built or is under construction for measuring accurately the changes in the crystallographical and optical constants of crystals for temperatures ranging from $-190°$ to $+1600°$C. and for hydrostatic pressures ranging from 1 to 2000 atmospheres.

The fact that in a crystal each of the component atoms is restricted largely to minute translational oscillations about a point, in other words is limited in its degrees of freedom, is exceedingly important from a thermodynamical standpoint. Thermodynamics is a general system of statistical mechanics applied to the energy relations involved in heat and work; because of its generality thermodynamics is applicable to a great variety of problems, but the mode of its application requires nice dis-

crimination in problems which are essentially vectorial in character, as are problems involving differences in directional crystal forces. A large number of the minerals which occur in nature are of the monotropic type and many of the reactions are examples of thermodynamically false equilibria and yet these may exist for geologic ages without change. In applying thermodynamical reasoning to problems of equilibria between crystals, it is essential that the individuality of the crystals be considered, especially as this introduces factors which may be superior in magnitude to the thermodynamical tendencies toward equilibrium, i.e. a configuration for which at the given temperature the total energy content is a minimum. Thus, to speak of the lack of crystallization in a volcanic obsidian because of an exceedingly slow rate of reaction, does not describe the situation adequately, because in the volcanic glass the internal friction at ordinary temperatures is so high that it is superior to the crystal forces and completely inhibits effective action on their part; the viscosity serves as a brake and may bring the crystallizing tendencies to a stop. Similar conclusions apply to the general application of thermodynamical equations to problems involving the elastic properties of crystals, especially to the deformation of a crystal under load.

In the treatment of problems of this nature which involve crystallization it is important to realize that the influence of certain forces which are grouped under the term "individuality" of the crystal may exceed in importance the thermodynamical tendencies toward equilibrium. In crystal as in other systems thermodynamical relations are fundamental, but equally fundamental are the vectorial and polar force-relations which heretofore have been little regarded because of the difficulty of defining and of measuring them satisfactorily. Many of the problems of crystal equilibria are of such a nature that in order to effect a complete solution neither thermodynamics alone is adequate, because of its inherent inability to treat vectorial and polar properties properly, nor is crystallography alone adequate, because it considers chiefly the single crystal. Progress can best be made by bringing to bear on the problem both thermody-

namics and crystallography. The recognition and delineation of the fields of application of thermodynamics and of crystallography in problems of crystal equilibria is an essential step in the solution of such problems; but before this can be done satisfactorily more quantitative data on interatomic crystal forces are required.

The rock-making minerals. As a good example of the kind of problem in which crystal configurations of certain types persist over a great range of conditions of formation, the rock-making minerals may be cited. The most remarkable fact in petrology is the relatively few rock-making mineral species, especially in igneous rocks. These few minerals persist the world over and constitute the major part of the rocks of the earth's crust; and yet their number can be counted on the fingers of the two hands—thus quartz, the feldspars, micas, amphiboles, pyroxenes, nephelite, and calcite predominate; magnetite, zircon, apatite are also common, but their total amount is small. This persistency of a few mineral species, notwithstanding great diversity in conditions of formation and in chemical composition, is fundamental. In magma solutions such factors as temperature, pressure, solubility relations, rates of reaction, change in composition by virtue of escape of volatile components, and crystal nucleation enter the problem; but it appears that, in spite of the great diversity possible in such complex chemical systems, the crystal groupings of the chemical elements, which do result, are exceedingly few in number. These groupings represent, of course, the resultant of all the forces involved; the problem is in part to ascertain the relative importance of these several factors. It may be inferred that possibly the dominating factor in the crystallization of a magma is the stability of certain crystal types or configurations and that these assert themselves notwithstanding tendencies toward other groupings which thermodynamically are more stable. Of crystallographic interatomic forces we know but little. The facts of observation are, however, too patent to be disregarded in any consideration of rock genesis, and are here cited as the kind of problem in which a better understanding of crystal forces and of crystals is

essential to an adequate solution. The study of crystals from the viewpoint of crystal forces is an integral part of geophysical and geochemical research.

MINERALOGY.—*Xanthophyllite in crystalline limestone.* ARTHUR S. EAKLE, University of California, Berkeley, California. (Communicated by EDSON S. BASTIN.)

The rare brittle mica xanthophyllite has not been reported from any localities other than those in the district of Slatoust in the Ural Mountains, where it, and its variety waluewite, were found.

The xanthophyllite described and named by Gustav Rose[1] was a wax-yellow mineral in scales and plates, occurring as a constituent of a talc-schist in the Shiskimskaya Mountains, in the Urals, and this yellow color was probably exceptional.

Many years later the green variety was found, and named waluewite by Kohscharof.[2] The waluewite occurred as a constituent of chlorite schist in the Nicolai-Maximilian Mine, near Slatoust. Small veins of calcite which occurred in the schist also contained flakes of the mineral, merely as inclusions, however. The original yellow xanthophyllite and green waluewite were schist minerals; so it may be of value to note the occurrence of the green waluewite in another locality, and as a contact metamorphic mineral in crystalline limestone, in association with monticellite.

The isolated hill of crystalline limestone and granodiorite situated at Crestmore, about eight miles west of Riverside, California, is one of the best studies in contact metamorphism that exists anywhere, and upwards of fifty mineral species, among them the recently described new mineral, wilkeite,[3] have been found in the same quarry. The white marbleized limestone rests as a capping upon a base of granodiorite, and the general metamorphism of the original limestone beds has probably been

[1] Pogg. Ann. d. Phys. u. Chem. **50**: 654. 1840. Also in his "Reise nach dem Ural," **2**: 120, 514, 527. 1842.

[2] Zeits. fur Kryst. **2**: 51. 1877. Also in his Mineral d. Russ. **7**: 346.

[3] EAKLE, A. S., and ROGERS, A. F. Amer. Jour. Sci. **39**: 262. 1914.

due to intrusion of, and contact with, this igneous mass. Metamorphism has been repeated, however, in portions of the rock mass by later injection of dikes and hot solutions, and in consequence parts of the hill have been mineralogically enriched by further development of lime-magnesia-silica minerals. The Crestmore waluewite was thickly disseminated in some of the sky-blue calcite of the Commercial quarry on the northeast side of the hill, as indicated by the specimens saved from destruction. It is said that tons of the sky-blue calcite containing the waluewite were quarried and used for road-making, for sugar refining, and for cement, and in consequence, all of it has disappeared.

The waluewite occurs mainly as isolated, hexagon-shaped, basal plates of a deep grass-green color. The sizes of the plates vary greatly, some measuring 3 to 4 cm. in diameter and 2 to 3 cm. thick. The average size of the crystals is about 5 mm. in breadth and 4 mm. in thickness. The plates are transparent with a brilliant and somewhat pearly luster, but the edges are dull, rounded and grooved, and the measured angles did not approximate any of the forms given by Kohscharof. The plates are very brittle with a hardness of 4–5. The thicker crystals show polysynthetic twinning like the micas, and under the microscope they extinguish in striated sectors and give a confused axial figure. The thinner crystals and cleavage plates give a good biaxial figure with an apparent optic angle of ahout 20°. Measurements of the optic angle in sodium light showed a variation from 12° to 18°. The optic axial plane is (100) and the mineral is optically negative. The refractive indices β and γ which lie in the basal section are practically the same and were determined as 1.660.

Several analyses of the xanthophyllite and waluewite from the Urals have been published and the analysis of the Crestmore mineral agrees with them.

The associated monticellite is scattered through the calcite as small masses and grains. It appears to be more segregated along the cleavage planes of the calcite rhombohedrons, and is often in close association with the flakes of waluewite and occasionally includes the waluewite. One large specimen shows a

wide band of massive monticellitė, indicating that it was an abundant mineral. The color is pale brown and luster somewhat greasy. There are no crystal faces visible. The analysis gave: SiO_2, 36.02; FeO, 2.82; CaO, 34.36; MgO, 24.74; Ign., 1.25; total, 99.19.

TABLE I

ANALYSES OF WALUEWITE FROM CRESTMORE AND SLATOUST

	1	2	3
SiO_2	16.74	16.39	16.85
TiO_2			tr.
Al_2O_3	42.70	43.40	42.33
Fe_2O_3	2.85	1.57	2.35
FeO	0.41	0.10	0.20
CaO	13.09	13.04	13.30
MgO	20.03	20.38	20.77
Ign.	4.49	4.39	4.60
	100.31	99.27	100.40

1. Average composition of waluewite from Crestmore, California. Sp. gr. 3.081.

2. Analysis by Nikolajen of waluewite from Nikolai-Maximilian Mine, District of Slatoust, Urals. Zeit. für Krys. **9**: 579. (Abstract).

3. Analysis by Clarke and Schneider of waluewite from Nikolai-Maximilian Mine, District of Slatoust, Urals. Amer. Jour. Sci. **43**: 379. 1892.

The association of the two minerals is of particular interest, because waluewite may be viewed as having the composition of monticellite with the spinel and alumina hydrate molecules. In the discussion by Clarke and Schneider of the constitution of the members of the clintonite group it was suggested that waluewite may have the monticellite molecule in addition to its spinel and olivine molecules, although no direct association of the two was then known.

The two Crestmore minerals are products of hydrothermal metamorphism of the limestone, and the waluewite has crystallized in a lime carbonate solution in which the monticellite molecule was the predominating component of the silicate mixture

and presumably governed the formation of the waluewite, the small excess of silica and all of the alumina entering into the waluewite which formed somewhat prior to the monticellite.

Monticellite occurred in large masses, while the waluewite was quite subordinate in amount. The composition of waluewite suggests a mineral mixture of monticellite + olivine + spinal + diaspore in the respective approximate ratio of 6 : 1 : 5 : 6.

The recrystallization of the limestone produced a pure blue calcite with coarse rhombohedral texture. Cleavage rhombohedrons several centimeters in diameter can be broken from the mass.

The source of the magnesia, alumina and silica is somewhat problematical. The original limestone was not especially dolomitic or argillaceous as the main limestone capping averages about 2 per cent magnesia and about the same in insolubles. The blue calcite with its monticellite, waluewite, vesuvianite, diopside, wilkeite, etc., is very localized in its development, occurring in patches and bands or zones. It suggests an occurrence near the contact with former dikes or apophyses of igneous rock, and it appears highly probable that the assimilation of the magnesian-felspathic constituents of these intrusions with the lime carbonate by the action of hot magmatic solutions had produced these localized occurrences of hydrometamorphic minerals.

BOTANY.—*Pamburus, a new genus related to Citrus, from India.* WALTER T. SWINGLE, Bureau of Plant Industry.

In 1833 Dr. Robert Wight described as a new species *Limonia missionis*, a small, spiny tree from the sandy coastal regions of southern India. In 1861 this species was referred to the genus Atalantia by Oliver, who notes, however, that it is "rather isolated in its general *facies* as well as by precise characters."[1] Subsequent botanical writers have followed Oliver in referring this plant to Atalantia.

[1] OLIVER, D. *Nat. order Aurantiaceae.* Journ. Linn. Soc. **5** (suppl. 2): 12. 1861.

In the course of a revision of the plants related to Citrus it has been possible for the writer to examine much material referred to the genus Atalantia and it has become evident that decidedly diverse plants have been put into this genus. The true Atalantias congeneric with the type species, *A. monophylla* (Roxb.) DC., have fruit resembling miniature oranges, with pulp vesicles somewhat like those of other citrous fruits. *Atalantia missionis*, on the contrary, has, as noted by Wight in the original description, a small fruit with cells "containing a very glutinous mucilaginous fluid." Besides this very significant distinction, *A. missionis* differs from *A. monophylla* and its congeners in having the anthers linear-oblong instead of broadly ovoid, and in having a tall, narrow disk supporting the ovary, instead of a very short, thick one. The leaves differ widely from those of the true Atalantias in texture and venation, being thick, glabrous, with both faces nearly alike, and velvety gray-green when dry, showing only a very few obscure lateral veins and no reticulate veinlets.

Because of these numerous points of difference, some of them of much taxonomic value in this group, it seems necessary to create a new genus, Pamburus,[2] to include this remarkable species.

Pamburus Swingle, gen. nov.[3]

Much-branched thorny shrubs or small trees; young branches angled, becoming rounded when older, with single stout sharp straight thorns at one side of the bud in the axils of the leaves. Leaves unifoliolate,

[2] From the Singhalese name *pamburu*.

[3] **Pamburus** Swingle, gen. nov., *Paramignyae* affinis, sed frutex vel arbuscula, foliis crassis, coriaceis, utrinque similibus, venis inconspicuis, petiolis brevibus, rectis, pulvinis carentibus, ovario disco magno innixo.

Folia unifoliolata, petiolis brevibus apteris; laminae crassae, siccitate cinereo-virides, superficiebus superioribus et inferioribus similibus, venis secondariis inconspicuis, tertiis carentibus; spinae singulae, rectae, axillares. Flores magnitudine mediocres, odoratae; petala alba, obovata, caduca; stamina libera, filamentis tenuibus, subulatis; stylus tenuis; stigma subglobosum diametro stylo multo majus; ovarium 5–4-loculare, ovulis in loculo binis. Fructus subglobosus, cortice ut in *Citro* carnosa, loculis 1–2-spermis, liquoris glutinosi plenis. Semina subglobosa.

Arbusculae vel frutices ramosi, spinosi, ramulis junioribus angulosis. Species typica, **Pamburus missionis** (*Limonia missionis* Wight). Habitat in India.

thick; lateral veins inconspicuous, not visibly connected by reticulate veinlets; petioles short, more or less margined but not winged, not articulated with the lamina. Flowers small, 5- or 4-merous, borne in short racemes in the axils of the leaves on rather long pedicels. Calyx small, 4–5-lobed; sepals acute. Flower buds globose when young. Petals 5 or 4, white, obovate. Stamens free, 8–10 (twice as many as the petals); filaments free, slender, glabrous; anthers large, erect, linear-oblong. Pistil stipitate, seated on the prominent cylindric disk; style slender, short, ending in the much thicker subglobose stigma; ovary subglobose 5- or 4-celled, with 2 ovules in each cell. Fruits globose, like a small orange in appearance, with the cells usually containing a single seed surrounded by a glutinous mucilaginous fluid (lacking true pulp vesicles). Peel rather thick, firm, with numerous oil glands. Seeds subglobose. Germination unknown.

Type species, **P. missionis** (*Limonia missionis* Wight), native to India.

The genus Pamburus differs from Paramignya in having short petioles, lacking the pulvini characteristic of the latter genus, and in the very different character of the leaves which are nearly veinless and very similar on both faces. The spines of Pamburus are straight or nearly so, not recurved as in Paramignya. Pamburus is a tree or shrub, not a perennial woody liane like Paramignya. Pamburus differs widely from Merope in the character of the fruit and seeds, and from Lavanga in having unifoliolate leaves. Hesperethusa, Triphasia, and Severina differ widely in leaf and fruit characters.

Pamburus belongs with the genera mentioned above in a group characterized by small soft-rinded fruits having the segments filled with a sticky fluid. The true citrous fruits differ from this group in having soft-rinded fruits, but the segments filled with pulp vesicles. The hard-shelled citrous fruits are again different and have large fruits with a hard, usually woody rind, though likewise cells filled with a sticky fluid.

In the peculiar structure of its leaves Pamburus is unique in the tribe Citreae, though possibly showing some analogy with the xerophytic Eremocitrus[4] of Australia.

Only one species of Pamburus is known:[5]

[4] SWINGLE, WALTER T. *Eremocitrus, a new genus of hardy drouth-resistant citrous fruits from Australia.* Journ. Agric. Research, **2**: 86. 1914.

[5] *Chilocalyx ellipticus* Turcz., cited in Index Kewensis and Hook. Fl. Brit. Ind. (**1**: 513.) as a synonym of *Atalantia missionis*, is probably based on *Atalantia monophylla*. It certainly is not synonymous with the present species.

Pamburus missionis (Wight) Swingle, comb. nov.

Limonia (?) *missionis* Wall. Cat. No. 6358. 1832 (*nomen nudum*).

Limonia missionis Wight in Hook. Bot. Misc. **3**: 291, *pl. 33*. 1833.

Atalantia missionis Oliv. Journ. Linn. Soc. **5** (suppl. 2): 25. 1861.

A much-branched shrub or small tree, armed with stout straight spines, these 2–3 cm. long, arising singly (or rarely in pairs?) on the side of the bud in the axils of the leaves. Leaves oval, oblong-obovate or elliptical, 6–10 cm. long, 2–4 cm. broad, very thick, coriaceous, glandular-punctate, the tip rounded, sometimes slightly emarginate, the base narrowed rather abruptly into the petiole, the margin entire, becoming gray and apparently crenate in drying; lateral veins inconspicuous, tertiary ones not apparent, the two faces very similar in appearance, drying to velvety gray-green unlike those of any other member of the subfamily Citratae. Flowers 12–20 mm. in diameter, fragrant, with small pointed sepals and 5 or 4 white obovate caducous petals about 1 cm. long. Pistil about 1 cm. long. Fruit about 2.5 cm. in diameter, orange-colored when ripe, with a thick peel dotted with oil-glands, 5–4-celled, the cells containing 1 or 2 seeds surrounded by a sticky gum.

TYPE LOCALITY: Tanjore District, Madras Presidency, Southern India.

DISTRIBUTION: Southern India and Ceylon, in low flat country near the coast.

The writer has had opportunity to study authentic cotypes, collected by Dr. Wight, in the Kew Herbarium, as well as other material from India and Ceylon.

POSSIBLE UTILIZATION OF PAMBURUS

It is possible that Pamburus is closely enough related to the true citrous fruits to serve as a stock upon which they can be grafted. The peculiar leaves of this species, unlike those of any other member of the orange subfamily, make it probable that it will be found to possess climatic or soil requirements different from those of related genera. This species has not yet been introduced into the United States, but it is hoped that it may be secured soon. It is native to southern India and Ceylon and, according to Trimen,[6] is rather common in the low country, chiefly in the dry region of Ceylon.

[6] TRIMEN, H. Handbook Fl. Ceylon, **1**: 228. 1893.

ETHNOBOTANY.—*Polynesian names of sweet potatoes.* O. F. COOK, Bureau of Plant Industry, and ROBERT CARTER COOK.

The same word, *cumara* or *kumara*, serves as a name for the sweet potato (*Ipomoea batatas*) among the Quichua or Inca people of Peru and in the Polynesian islands. The fact was recognized over half a century ago when Seemann recorded the use of the word in Ecuador. In the Urubamba valley of southern Peru, on the eastern slope of the Andes below Cuzco, there are two native names for different classes of sweet potatoes, *apichu* for the sweet varieties and *cumara* for those that are merely starchy.[1]

That an important crop plant should have the same name among the Polynesians as in the interior of Peru might be taken as proof of a recent introduction, just as the Polynesian name *poaka* was taken at first to demonstrate that pigs were brought by Europeans. Later it was pointed out that the Polynesian pigs could not have come from Europe because they belonged to an Asiatic or Malayan species. The name *poaka*, in spite of its obvious likeness to the Spanish *puerco* or the English *porker*, is accepted by the best authorities as a genuine Polynesian word.

To insist that *kumara* can not be a Polynesian word because it appears in the Quichua language of Peru would be like saying that *puaka* could not be Polynesian because the Greeks and Romans had *porcus*. If *kumara*, *poaka*, or other words for particular animals or plants reappear in different languages, the fact needs to be recognized and taken into account in tracing the origins of the domesticated species and their relation to the extension of agriculture in prehistoric times.

Thus far the word *kumara* seems not to have been challenged as a foreign element by any student of the Polynesian language. Certainly it does not appear un-Polynesian, in view of the frequent occurrence of the sounds and syllables of which it is composed. Among such words as *kakara* (odor), *kapura* (fire), *kororo* (sea-gull), *korora* (mussel), *mamara* (charcoal), *marara* (fly-

[1] COOK, O. F. *Quichua names of the sweet potato.* Journ. Wash. Acad. Sci. 6: 86. 1916.

ing-fish), *tauama* (outrigger canoe), and *tamara* (palm leaves), *kumara* seems fairly at home. It is also very widely distributed, with only slight modifications, conforming with the changes of consonant sounds in some of the dialects. The following variations of the word are brought together by Tregear: *kumaa* (Marquesas), *kumala* (Tonga), *uala* (Hawaii), *umala* (Samoa), *umara* (Tahiti), *uwala* (Hawaii), with *kumara* recorded for New Zealand, Rarotonga, Easter Island, Mangareva, and Paumotu. *Hooarra* was recorded as the Hawaiian name of the sweet potato in 1778, by Captain Cook's expedition.

Possible cognates or derivatives of *kumara* are numerous in the Maori language, including *kumanu*, to tend carefully; *kumore*, cape or headland; *kumete*, dish, bowl, or trough; *kume*, to pull out; *kumu*, to draw back. *Whakakumu* is the name of one of the New Zealand varieties of sweet potato, and *kumu* also means fist, or portions of food squeezed out with the hand. The growing sweet potato crop was called *maara* in New Zealand, reminding of *malla*, the Quichua word for a young plant. *Kamala* is a word for thatch in Hawaii, where *kumara* vines were often used for this purpose. *Kalau* is another Hawaiian word which means either a thatch of leaves or vines of sweet potatoes, or to work inefficiently, the sweet potato materials being but poorly adapted to the purpose. *Kalina* is defined by Andrews as "old potato vines that have done bearing," or "a garden of potatoes where the old refuse potatoes only remain." *Kalina* and *ilina*, the latter meaning burial-place in Hawaii, are suggestive of the Quichua word *illuni*, meaning to dig for roots. Other Quichua words are *cullquini*, meaning "to dig with a stick," and *culluna*, a silo or subterranean storehouse.

In New Zealand the words *kapuka* and *kepura* are both said to mean "a handful of potatoes." Two native New Zealand plants, *Pomaderris elliptica* and *Quintonia serrata*, are called *kumarahou*, but the relation to *kumara* is not indicated. *Hau* is a general name for *Paritium tiliaceum*, a shrub widely cultivated among the Polynesians for the sake of its fibrous bark.

In Hawaii, where the name of the sweet potato is softened into *uala*, the same word is applied to the large muscles of the upper

arm, by an analogy easily understood. In Easter Island, where the full form of the word *kumara* is used, there is a word, *komari*, also applied to parts of the human body. *Komala* means pleasant in Hawaii.

Dried sweet potatoes are called *kao* in New Zealand and *ao* in Hawaii, where the same is applied to dried *taro* or to Alocasia. *Koiri*, in New Zealand, means "to plant potatoes," and a variety of sweet potatoes is called *koiwi*. Other meanings of *kao* are rib, core, shoot, or terminal bud of a plant. The Hawaiians called the sea-bread or hardtack of the English ships *ao* when they first saw it. *Kao* suggests *kaya*, the Quichua name for dried *ocas* (Oxalis). *Kauno*, in Quichua, means withered or dried in the sun; *kauñu*, dried cane or corn stalks; potatoes after freezing, *chuño* or *chuñu;* potatoes left behind in the field, *koyo*. *Kauñu* and *chuñu* are obviously related, like the German *kauen* and the English *chew*.

According to Martius the sweet potato is called *coundi* by two tribes of Indians in Brazil, while in Florida *kunti* is the native name of the edible cycad Zamia. In the Lucumayo valley of southern Peru the rootstocks of Xanthosoma, an aroid closely similar to the taro of the Polynesians, are dried "to make *chuños*." In the vicinity of Ollantaytambo, Peru, a native medicinal plant with thickened roots, somewhat resembling the dried *ocas*, is called *kayakaya*.

The Hawaiians had two words, *haaweawee* and *pahulu* for second-growth sweet potatoes, or those that spring up from roots left behind at the harvest, just as the Quichuas have *koyo, acacha, cachu*, and *ihua* (eewa) for potatoes left in the ground or growing in the old fields. In New Zealand gleanings of root crops are called *wairan*, but the word *kaunga* is applied to sweet potatoes that will not grow when planted. Another meaning of *kaunga* is "smelling unpleasantly," which would be a natural connection if the word related to stored potatoes that had begun to decay.

In some of the Polynesian islands *kao* is not defined as relating to dried sweet potatoes, but is used in the sense of "grabbling," taking a few of the roots from the hill without disturbing the plant. In explaining the connection Tregear states that the im-

mature roots are used to make *kao*, presumably because they dry better while the flesh is still starchy, before much sugar is formed.

Related perhaps, to *kao* and *kaunga*, are *kauahi*, *kauati*, *kauhure*, *kaunaki*, and *kaunoti*, which are Maori names relating to the sticks that are used for making fire by friction, the wood for this purpose being kept, of course, very dry. *Kauati*, in the Paumotu islands, means to make fire; *auwaki* are fire-sticks in Hawaii, and *kahu* is fire or to burn. In New Zealand again, *kauhuri* means "to dig; to turn over the soil." *Huri*, in some of the islands, means to dig, but in others seed, suckers, or offshoots used for planting. The Quichua name for a green corn-stalk or sugar-cane is *huiro*.

That *kao* and *kahu* may be related words is further suggested by the fact that one of the Hawaiian varieties is called *kahe* and one of the New Zealand varieties *pokerekahu*. The Maori name of the yam is *uwhikaho*. Although in the Maori language *kahu* is not reckoned as a name of fire, it is the name of the hawk, the god of fire, reckoned as a child of the fire-goddess Mahuika. Moreover, *Kahukura* was the name of the rainbow-god of the Maoris, and also the name of the man who, according to one tradition, brought the *kumara* to New Zealand, together with the taro, the bottle-gourd, and the yam. The traditions indicate that the dried sweet potatoes had great importance in former times among the Maoris, perhaps as affording their only supplies of food that could be kept over from one season to another.

In addition to the drying of sweet potatoes to make *kao*, the leaves of the plant were eaten, as they are by the Quichuas in South America. The Hawaiian word *palula* is defined as the leaf of the sweet potato, and as a dish made by roasting sweet potato leaves on hot stones. The word resembles *pahulu*, defined as "potatoes of a second growth," and *ponalo*, "the dying or drying up of potato tops.'"

The status of sweet potato varieties among the Polynesians affords the most definite evidence of long-standing possession and familiarity. While almost nothing in the way of detailed

information regarding the Polynesian varieties seems to have been placed on record, the facts that have been noted incidentally by writers on ethnology and language are sufficient to show that numerous varieties of sweet potatoes are recognized and distinguished by native names, in the same way that large numbers of potato and other root crop varieties are named among the Quichuas in Peru, although very few of these names have been recorded in the published vocabularies of the Quichua language.

Although domesticated plants afford significant data for the study of the contacts and relations of primitive peoples, plant names have seldom received much attention from philologists and ethnologists. From New Zealand, however, about 40 native names of varieties of sweet potato have been published, from different districts, the largest list, containing 25 names, supposed to represent nearly as many different sorts.[2]

A similar diversity of varieties might be found in other islands, but from most of the groups no varietal names have been recorded, while in others a few names have been noted incidentally, such as Manana, "the name of a kind of sweet potato," in Hawaii. In the same group "very small potatoes with red veins"

[2] Three lists of native varieties of sweet potato have appeared in the Journal of the Polynesian Society (**2**: 102, **3**: 144, and **3**: 237). Arranged in alphabetical order to facilitate comparison, the names are as follows:

List 1. (Locality not given.) Kaihaka, Kaipo, Kanawa, Kaoto, Korehe, Kotepo, Maomao, Taurapunga, Toroamahoe, Tukau, Waina, Waniwani, Whakakumu. The variety called Waina is noted as having been introduced early in the nineteenth century.

List 2. East Cape district: Anutipoki, Huiupoko, Kawakawa, Kerikaraka, Kokorangi, Koreherehe, Makakauere (Makakauri or Matakauri), Makutu, Matawaiwai, Moii, Monehu, Ngakaukuri, Paea, Papahaoa, Para-karaka (same as Makutu), Paretaua, Patea, Pokere-kahu, Puatahoe (said to produce flowers), Punuiarata, Tanehurangi, Taratamata, Taurapunga, Toroamahoe, Waiha (or Waniwani) (same as Huiupoko), Wini. All of these varieties are said to have been cultivated in New Zealand before the arrival of Europeans.

List 3. West Coast of the North Island: Anurangi, Aorangi, Arikaka, Kahutoto, Kopuanganga, Kotipu, Monenehu, Pehu, Pokere-kahu, Rangiora, Taputini, Toroamahoe.

Other New Zealand varieties mentioned by Tregear are Koiwi, Ruamataki, and Torowhenua, the last name said to be used also in the Marquesas group, where Maori is also the name of a sweet potato variety.

and "water-soaked potatoes" are called *kokokooha*, *koko* being the name of the fibers of the leaf-bases of the coconut palm, or a net of braided strings to hold a calabash. One of the Hawaiian varieties is called Apo, while *apoapo* means a hill of sweet potatoes, reappearing in New Zealand as *apuapu*. Other Hawaiian names for varieties of sweet potatoes mentioned in Andrews' *Dictionary* are Kahe, Kipawale, and Koloaha. The variety called Kihi is said to be "the ancient potato of Hawaii."

Some writers have thought that the sweet potato must be a recent acquisition among the Polynesians, because of the many myths and traditions relating to its introduction. But such evidence appears to have a different signification when we consider how much the Polynesians were given to family pride and genealogies. To say that one's forefathers came in the canoe that brought the *kumara* certainly did not mean that the family was recent, but was the Maori way of claiming a Mayflower ancestry. White has given us a detailed account showing how acutely the subject was debated by the Maoris, and the intensity of feeling is reflected in the care taken by that author to report the controversy in such a way as to avoid the appearance of taking sides and thus offending some of his native neighbors.

If weight is to be given to traditions of the introduction of sweet potatoes, account must also be taken of the myths and cosmographies that represent the sweet potato as one of the primeval possessions of the human race, the first plant to be recognized among the heavenly gifts. Thus the Maori pantheon began with Void (Kore) and Darkness (Po) as the parents of Heaven (Rangi) and Earth (Papa). In the third generation of deities came Tane, god of trees, forests, and birds; Tangotango, god of day and night; and Wai-nui, the goddess of water. Tane figures as the grandfather of sweet potatoes and the bottle-gourd, the former by his oldest child, the latter by his youngest. The passage treating of the sweet potato is as follows:

> Tane took to wife Hine-rau-a-moa and begat Rongo-ma-Tane, who was the parent, origin, or personification of the *kumara* (sweet potatoe) and of cultivation and the arts of peace; and Hine-te-iwaiwa, the guardian of motherhood; and Tangaroa, the Polynesian Neptune, who

stands in the same relation to the ocean and the fish thereof as does Tane to forests and birds.[3]

In this, as in many other myths and traditions of the Maoris, the sweet potato has precedence over all other crops and plants, and it may be significant that the bottle-gourd, another plant that the Polynesians shared with the natives of South America, is in this case the second in order of consideration, before the taro or other plants cultivated by the Maoris.

Tregear has made a careful study of the ancient religious myths of the Polynesians and finds many that are closely parallel to those of the Mediterranean countries. He compares the god Maui of New Zealand with the Egyptian Osiris, and his wife Hina or Pani with Isis, Ceres, Diana, and other goddesses of agriculture and fecundity among the Asiatic and Mediterranean peoples. Maui is associated with the sun and Hina with the moon. *Kura-a-Maui* is recorded as a poetic name of the sweet potato among the New Zealanders, *kura* meaning red or royal, or a wreath of red flowers, as worn by the ancient heroes, according to the traditions. There was also a sacred or priestly name of the sweet potato, *kurawhiti*. Maui was invoked in planting *kumaras*, but the formal incantation was addressed to

[3] Best, E. *Notes on Maori mythology*. Journal of the Polynesian Society, 8: 95.

The *kumara* figures in many of the myths of this collection, including several that have to do with the sun and stars, as in the following passages:

"The sun has two wives. One wife lives in the south; her work is the cultivation of food, and her name is Aroaro-a-manu or Raumati (Warmth or Summer). The other wife is Hine-takurua (Winter); she dwells on the ocean, and her task is the taking of fish. In the winter the Sun goes to the ocean and dwells with Hine-takurua. In the month O-toru [of the Maori year] the sun returns to land to his wife Raumati, who cultivates the *kumara*. It is then summer."

"Hoko-kumara is a name for Matariki (Pleiades). When Matariki rises in the east the *kumara* is sown."

"When Whanui [the star Vega] is seen flashing above the eastern horizon as autumn approaches, then the cry resounds: *'Ko Whanui E-E! Ko Wahnui!'* For that is the sign for taking up the *kumara* crop. If the *kumara* [sweet potato] be not dug then, the crop will be spoilt and will not keep. Such *kumara* as are left in the ground become *houhunga*, good to eat but will not keep. Potatoes are dug in the month Pou-tu-te-rangi. If left too late they will be spoilt, in which state they are termed *tauhere* or *puakiweu*."

Pani. Large sweet potatoes of a special form were sacred to Pani and were not eaten. They were called "Pani's canoe" and the finding of them was considered a special omen from the goddess, presaging fertility. Boats were among the symbols of Isis, and one of her names was Pania.[4]

In New Zealand, elaborate ceremonies were performed when the *kumara* crop was planted, the seed tubers being selected with the greatest care by a priest, as was also the place in which they were planted. Over each tuber a special incantation was chanted and it was placed in the ground with the head slightly raised and pointed toward the east. One of the legends dealing with the introduction of the *kumara* tells how those who went to get them traveled toward the rising sun, and how their canoe was kept by enchantment for many days in the same place in the ocean, meaning, perhaps, that no land was sighted for many days.

Several times during the growth of the *kumara* crop religious rites were observed, and when the roots were harvested still another series of ceremonies was enacted, the first fruits of the crop being given to the gods of *kumara*.[5] The extent to which the religious precautions were carried is indicated by Tregear's definition of the word *whakamahunga:* "The ceremony of making sacred those who planted or dug up the *kumara*. After the first-fruits had been offered to Pani, the cultivators became common (*noa*), or no longer under restriction."

To judge from the facts noted in this brief review of the subject, the word *kumara* must still be accepted as the Polynesian name of the sweet potato, notwithstanding that the same word is applied to the same crop among the Quichuas of the eastern valleys of the Andes, below Cuzco. In view of the general distribution of the plant and its name among the Polynesians, the use of the leaves and the dried roots, and their special names, the development and naming of numerous varieties, and finally the many myths and traditions connected with the sweet potato,

[4] TREGEAR, E. *Asiatic gods in the Pacific.* Journal of the Polynesian Society, 2: 145. 1893.

[5] WHITE. *Ancient History of the Maori,* vol. 3, preface.

it does not seem reasonable to believe that the introduction of the plant occurred within the period of exploration of the Pacific by Europeans. Nothing need be said of the reports of the early explorers who found sweet potatoes already in the islands.

If the sweet potato had come to the Polynesians in recent times from an outside source it is practically inconceivable that the same name should have been distributed and adopted in so many islands. In this respect there is a notable contrast with the many distinct names for sweet potatoes among the native tribes of the American continent. The many traditions or myths regarding the *kumara* in the Pacific may mean nothing to which any definite significance can be attached, but at least they show how deeply the *kumara* was embedded in the existence of the islanders. The sweet potato, like the coconut palm, had relatively greater importance among the Polynesians than in other parts of the world.

PHYSIOLOGY.—*The basal energy requirement of man.*[1] EUGENE F. DU BOIS, M.D.

It is not too much to say that the science of nutrition is founded on the study of the basal energy requirement. Therefore it seems advisable to spend our time today on this aspect of the subject as an introduction to the subsequent lectures of the series. First we shall consider the definition of the term, basal energy requirement, next the manner in which it is studied, and finally the factors by which it is influenced in health and disease.

The energy requirement of a man is represented by the number of food calories, or heat units, required to balance the calories of his heat production. The two are equal, because food oxidized in the body gives off just as much heat as food burned outside the body. The basal requirenent is the minimal requirement or lowest heat production, and this condition is found only when an individual is lying down, at complete rest in the morning,

[1] A lecture delivered before the Washington Academy of Sciences, April 7, 1916. From the Russell Sage Institute of Pathology, in affiliation with the Second Medical Division of Bellevue Hospital, New York.

fourteen hours or more after his last meal. There are many synonyms for the term basal energy requirement, and it has seemed advisable to group them in a list so as to straighten out misunderstandings.

SYNONYMS OF BASAL ENERGY REQUIREMENT

Basal metabolism	"Nüchtern" metabolism
Basal caloric requirement	Post-absorptive metabolism
Basal caloric production	Total energy exchange
Basal heat production	Total gaseous exchange
Minimal metabolism	Total respiratory exchange
Total metabolism	

Of all of these synonyms the term basal metabolism is perhaps the best and most scientific. Metabolism includes the absorption of foods, their oxidations and transformations into body constituents, and also the later oxidations of these tissues. Such are the energy exchanges of the body, taking place with the consumption of oxygen and the formation of carbon dioxid, these gases being carried to and from the blood by means of the respiratory apparatus.

On looking over this formidable list of synonyms one gets the impression that scientists have spent much time in coining phrases and have tried to make two words grow where one grew before. Still we can have the recompense of knowing that when we have understood the term basal metabolism we have mastered a considerable portion of the dictionary.

Lavoisier was the first to make experiments on the respiratory metabolism and to grasp their significance. A long time afterwards Pettenkofer and Voit constructed the famous respiration chamber in Munich that gave Voit the data on which he founded our modern science of nutrition. His pupil Rubner with his own hands constructed a respiration chamber which was at the same time a calorimeter. By means of this Rubner was able to prove that foods are oxidized in the animal body in very much the same way that they are oxidized in the bomb calorimeter or the Liebig combustion furnace. The process is slower but just as complete, except for the urea portion of the protein molecule. No heat

is lost, for the law of the conservation of energy applies to the animal organism.

Meanwhile Zuntz and his pupils were making very important contributions to the science, using an apparatus which collected the expired air during periods ten to twenty minutes long. They were the first to grasp the importance of the modern standard conditions used in determining the basal metabolism. Their subjects were studied in the morning before breakfast, lying relaxed on a couch. Magnus-Levy examined a large number of patients in this manner and made great advances in our knowledge of the metabolism in disease. Zuntz, Loewy, and Durig used a portable apparatus in the study of the physiology of walking and other forms of muscular exercise.

America's greatest contribution to the science of nutrition was the Atwater-Rosa calorimeter, devised in Middletown, Connecticut. This was a small chamber about the size of a ship's state-room, equipped with a folding bed, a chair, a table, and a stationary bicycle. In it a man could live for a week or two, comfortably, but perhaps monotonously. His heat production was measured in two different ways. First, by the method of direct calorimetry, which determined by physical methods the heat of vaporization and of radiation and conduction; second, by analysis of the oxygen consumption and carbon dioxid production the grams of protein, fat, and carbohydrate oxidized each hour, this being the method of indirect calorimetry. Results obtained by these entirely different methods agreed perfectly. Atwater and his associates, Rosa and Benedict, established the fact that the law of the conservaton of energy applied to man. They also made important contributions to our knowledge of the utilization of foods, and of the dietary requirements under various circumstances. After the retirement of Atwater two groups of his assistants carried on his work. Langworthy and Milner moved with the famous calorimeter to the Department of Agriculture in Washington. Benedict and Carpenter built several new calorimeters and established in Boston the Nutrition Laboratory of the Carnegie Institution of Washington. Here they have not only made great advances in technique but have also

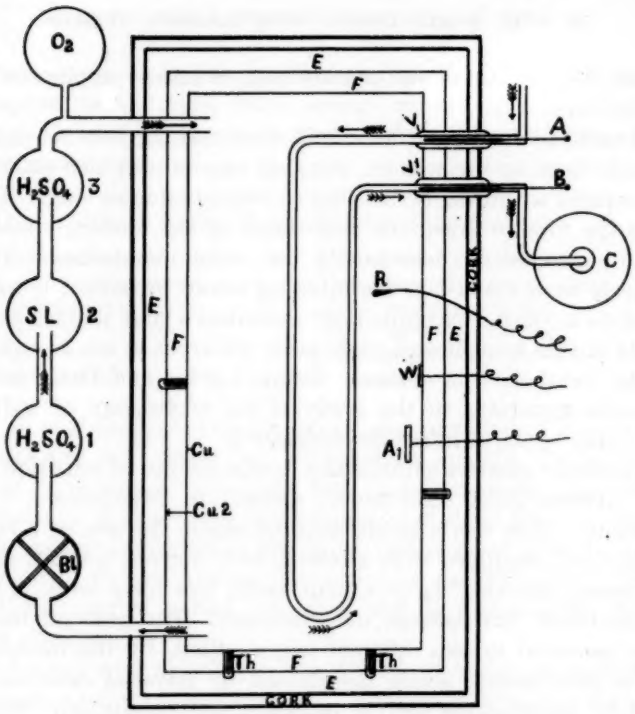

Fig. 1.—Schematic diagram of the Atwater-Rosa-Benedict respiration calorimeter.

Ventilating System:

O_2, Oxygen introduced as consumed by subject.

3, H_2SO_4, to catch moisture given off by soda lime.

2, Soda lime to remove CO_2.

1, H_2SO_4 to remove moisture given off by patient.

Bl., Blower to keep air in circulation.

Indirect Calorimetry:

Increase in weight of H_2SO_4 (1) = water elimination of subject.

Increase in weight of soda lime (2) + increase in weight of H_2SO_4 (3) = CO_2 elimination.

Decrease in weight of oxygen tank = oxygen consumption of subject.

Heat-Absorbing System:

A, Thermometer to record temperature of ingoing water.

B, Thermometer to record temperature of outgoing water.

V, Vacuum jacket.

C, Tank for weighing water which has passed through calorimeter each hour.

W, Thermometer for measuring temperature of wall.

A1, Thermometer for measuring temperature of the air.

R, Rectal thermometer for measuring temperature of subject.

Direct Calorimetry:

Average difference of A and B × liters of water + (gm. water eliminated × 0.586) ± (change in temperature of wall × hydrothermal equivalent of box) ± (change of temperature of body × hydrothermal equivalent of body) = total calories produced.

Th, thermocouple; *Cu*, inner copper wall; *Cu*$_2$, outer copper wall; *E*, *F*, dead air spaces.

made experiments on many individuals under a great variety of conditions. Their bed calorimeter in particular has been of great service in the study of the basal metabolism.

The most ingenious apparatus constructed for the study of metabolism is the small calorimeter of Langworthy and Milner. In this the temperature control is automatic and small electrical instruments day after day perform work that exhausts an experienced man after a few hours. Most calorimeters require two or three men in constant attendance, but theirs will run accurately all by itself.

The small calorimeter constructed by Dr. H. B. Williams for Lusk at the Cornell University Medical College in New York City has given results which are technically perfect even in short experimental periods. Only those who have worked in the subject can appreciate the brilliant planning of Lusk's experiments on dogs and their profound significance in the study of the fundamental laws of metabolism. As a result of this work on animals and some work on patients with the small "unit" respiration apparatus devised by Benedict, it seemed advisable to construct a calorimeter for the study of disease. This was made possible by the trustees of the Russell Sage Institute of Pathology, who supplied funds to Dr. Lusk sufficient for the construction and maintainence of a calorimeter and metabolism ward in Bellevue Hospital, New York.[2]

This apparatus, which was built by Riche and Soderstrom, is the latest development of the apparatus of Atwater and Rosa as improved by Benedict, Milner, Williams, and others. It is about the size of the lower berth of a sleeping car and is provided with a comfortable bed, a shelf and a couple of windows. The subject of the experiment lies quietly for three or four hours in the well ventilated box at a comfortable temperature. During this time his heat production is being measured by the independent methods of direct and indirect calorimetry.

The direct method depends on the physical measurement of the heat of radiation and conduction and also of vaporization, about one quarter of the total heat produced being eliminated by evaporation of water from skin and lungs. The indirect

[2] Archives of Internal Medicine, 15: 793. 1915.

method is purely chemical. The carbon dioxid production of each hour is measured, also the oxygen consumption. Knowing these and the nitrogen elimination in the urine, we can calculate out the grams of carbohydrate, fat, and protein metabolized each hour, and from their well known caloric values can determine the total heat production. In normal controls the two methods agree very closely, if we take the averages of all the experiments made. Even in periods as short as one hour the agreement is usually within 5 per cent.

This calorimeter in Bellevue is particularly well adapted to observations on patients. It is situated in a room next to a small metabolism ward where the food can be weighed out accurately and complete twenty-four hour specimens of urine collected. The experimental period within the chamber is only three hours, as contrasted with the long periods of one to ten days needed in the old Atwater-Rosa chamber in Middletown. The patient lies on a comfortable bed, breathing pure air at a uniform temperature. Even patients who are seriously ill can serve as subjects of the observation without the slightest harm being done. As a matter of fact they are greatly benefited, because their diets can be arranged scientifically as a result of the information obtained in the calorimeter.

In order to understand the results obtained in disease we must first consider the basal metabolism of normal men. With most individuals this is surprisingly uniform from day to day and from year to year. Of course the heat production of a man depends largely on his size, but it is by no means proportional to the body weight. A large man gives off more heat than a small man but for each kilogram of weight the small person has the higher metabolism. On the other hand the metabolism of men of various sizes and shapes is rather closely proportional to the surface area of the body. Many years ago Rubner established this law of surface area and was able to show that mice, rabbits, dogs, men, and horses had almost the same metabolism per square meter of skin.

Up to the last few years we were obliged to estimate the surface area of men by Meeh's formula which was simple but, unfor-

tunately, not accurate. Recently a better method was devised by Mr. Delafield Du Bois. This so-called height-weight formula can be expressed in a chart which enables one to find the approximate surface area if the height and weight of the individual be known. Using it to recalculate the results obtained upon normal persons, we find that the average heat production of men between the ages of twenty and fifty is about 40 calories per square meter per hour. There is a normal range of variation amounting to plus or minus 10 per cent from the average, and a few apparently normal individuals may depart as much as 15 per cent from the mean. Curiously enough very fat people and very thin ones have almost exactly the same heat production, measured in this way, while there may be a difference of 30 or 40 per cent between the two groups if we base the calculations on kilograms of body weight.

The level of the metabolism varies greatly with age. During the first few days of life it is very low, then rises rapidly during infancy, and reaches its highest level in the almost unexplored period between the ages of two and six years. After this it falls rapidly until about the eighteenth year when the curve flattens out. Between the ages of twenty and forty there is comparatively little change, but after this a slight fall, so that by the eightieth year the line is about 10 per cent below the average level for the ages of twenty to forty. There seems to be a stimulation to the basal metabolism during the period of growth.

Women show an average basal metabolism about 7 per cent lower than that of men of the same age. Athletes are about 7 per cent higher than men of sedentary habits. Confinement indoors or in bed reduces the metabolism, as does cage life for a previously active dog. Prolonged undernutrition can reduce the metabolism 30 or 40 per cent. Benedict's subject Levanzin, who fasted for thirty-one days, showed a marked reduction in basal metabolism, amounting to about 23 per cent after three weeks starvation.

The basal metabolism is always measured fourteen hours or more after the last meal, because food stimulates the heat production. A meal containing 60 grams of protein can increase the

metabolism 10 or 12 per cent for six or seven hours. One hundred grams of glucose may cause as great a rise, but for a shorter period. The stimulation from fat takes place much more slowly and does not reach its maximum until six hours after the meal. This stimulation caused by food is the specific dynamic action described by Rubner and studied in detail in the last few years by Lusk at the Cornell Medical College, New York City.

Muscular work affects metabolism to far greater extent than all other factors combined. Even walking at a moderate gait may increase the energy consumption threefold, and riding on a bicycle ergostat may increase it sixfold. Work of this type is done with an efficiency of 22 per cent. Only 78 per cent of the energy consumed is wasted, the rest being transformed into mechanical work. This is better utilization of fuel values than is found in machines that use coal. The body works more economically than a steam engine, but we can see why a lumberman in the Maine woods needs 9000 calories of food a day, which is three times as much as most of us consume and six times as much as our requirement would be were we to maintain it at its basal level by staying motionless in bed all day without food.

BASAL METABOLISM IN DISEASE

It has been possible at Bellevue Hospital to study in detail a large number of patients with typhoid fever. During the active stage of this disease, when the temperature maintains itself at 104° Fahrenheit, there is an increase in the basal heat production amounting to 40 or 50 per cent above the normal. The significance of this is appreciated if we remember that most doctors keep their typhoid patients on very small diet for weeks at a time. The result of such underfeeding is a profound wasting away of the patients own tissues, with great loss of weight and the addition of the symptoms of starvation to those of typhoid fever. Shaffer and Coleman, on the basis of studies of the nitrogen of metabolism, advocated a high calory diet in this disease. Dr. Coleman and the writer have studied the effects of such

liberal feeding by means of the small Benedict apparatus and of the Sage calorimeter. Curiously enough the taking of food does not stimulate the heat production nearly so much in typhold fever as in health, and patients on the high calory diet have no greater caloric production than those on the starvation diet. This shows how groundless was the old dread of fanning the fever by giving food. It seems to be well established that there is a toxic destruction of protein in typhoid fever. Even if we give the patient plenty of protein and enough calories in food to meet his caloric output, he will show a steady negative nitrogen balance. This phenomenon indicates that protein is broken down faster than it can be reconstructed. If we wish to maintain a typhoid patient in nitrogen equilibrium we must give him 4000 or 5000 calories a day, whereas his calculated output seldoms exceeds 3000 or 3500 calories. Patients do very well on these large diets if they be carefully administered; and at the end of the fever they are well nourished, instead of starved. The proper food in large amounts does not increase the intestinal symptoms.

The disease which has the greatest effect on metabolism is exophthalmic goiter, sometimes called Graves' disease. This is due to an overactivity of the thyroid gland, situated in the neck. Patients who suffer from this hyperthyroidism usually show some swelling of the gland, protrusion of the eyes, nervousness, large appetite, and warm, moist skin. In severe cases of the disease the resting metabolism may be increased 75 to 100 per cent above the normal level. This explains the great demand for food and the marked loss in weight if the diet be not liberal. It also explains the warmth of the skin, since each square meter of surface has to eliminate 75 to 100 per cent more heat than normal. There is also a disease called myxoedema in which the secretion of the thyroid gland is diminished. Patients with myxoedema are lethargic and have small appetities and cool dry skin. Their heat production is much below the normal, but if extract of thyroid gland be given them the normal level is attained once more and their symptoms disappear.

There are several other diseases in which the metabolism is increased 20 to 40 per cent. Among these may be included severe anaemias, cancer, severe cases of heart or kidney disease, high fevers, and perhaps other conditions that have not yet been studied. Patients who are not very ill show little change from the normal in their basal metabolism, and their food requirements are those of normal men under similar conditions.

DIABETES

In the very important disease of diabetes there are profound changes in the metabolism of all the foods. The study of these changes has thrown an enormous amount of light on the transformations of the food-stuffs which take place in normal individuals, and physiology owes a great debt to the study of this pathological condition. In severe cases the body being unable to oxidize any carbohydrate food, eliminates it in the urine as glucose. Proteins are incompletely oxidized, and about half of the protein molecule is changed into glucose and eliminated as such. Fats are incompletely metabolized, reaching the stage of beta-oxybutyric acid, which circulates in the blood as a poison in diabetics because the tissues are unable to oxidize it beyond this stage as they do in health. The level of the total heat production is not much changed in diabetes in spite of this disturbance of the intermediary metabolism. Direct evidence of the severity of the disease can be obtained by the use of the calorimeter or any other form of apparatus which determines the respiratory quotient. It is the respiratory quotient which tells the exact amount of carbohydrate that the patient is oxidizing. Severe cases can oxidize none; mild cases can derive 20 to 40 per cent of their calories from carbohydrates.

Quite recently Dr. F. M. Allen, of the Rockefeller Institute, has found that patients with severe diabetes are much benefited by periods of fasting and low diet. In almost all cases the sugar can be made to disappear from the urine and stay away as long as the diet is restricted. Several patients so treated have

been studied in the calorimeter in association with Dr. Allen, and it has been found that during the period of low diet there is a great reduction in the level of the basal metabolism. The organism adapts itself to the new conditions and seems to straighten out its internal difficulties when living economically.

In this short lecture we have been able to discuss briefly a few of the factors which influence the basal metabolism in health and disease. It is only through a study of such factors that we can place dietetics and particularly hospital dietetics on a scientific basis. In most institutions the patients are fed according to customs and habits inherited by trained nurses from previous generations. Perhaps in the course of years the food of sick men may be as scientifically administered as the food of the chickens and cows on a modern farm.

ABSTRACTS

Authors of scientific papers are requested to see that abstracts, preferably prepared and signed by themselves, are forwarded promptly to the editors. Each of the scientific bureaus in Washington has a representative authorized to forward such material to this journal and abstracts of official publications should be transmitted through the representative of the bureau in which they originate. The abstracts should conform in length and general style to those appearing in this issue.

TERRESTRIAL MAGNETISM.—*Results of observations made at the United States Coast and Geodetic Survey Magnetic Observatory near Honolulu, 1913 and 1914.* DANIEL L. HAZARD. U. S. Coast and Geodetic Survey Serial Publication No. 21. 1916.

This publication is in continuation of the series giving the results obtained at the Honolulu magnetic observatory since its establishment in 1902. It contains a summary of the monthly determinations of the scale-values of the horizontal intensity and vertical intensity variometers; the base-line values derived from the weekly absolute observations; diurnal variation tables for the magnetic elements D, H, and I, the total force F, and the rectangular components X, Y, Z; hourly values of D, H, and Z, together with daily and hourly means for each month; a tabulation of the earthquakes recorded on the seismograph; a list of the magnetic disturbances of considerable magnitude, and reproductions of the magnetograms showing the more marked disturbances. Attention is called to the fact that beginning with 1913 intensity results obtained by this Bureau have been reduced to the international standard of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. Published results for earlier years must be diminished by one part in a thousand to reduce them to that standard.

D. L. H.

PHYSICS.—*Photometry of gas-filled lamps.* G. W. MIDDLEKAUFF and J. F. SKOGLAND. Bureau of Standards Scientific Paper No. 264. 17 pp. 1916.

The introduction of an inert gas into the bulb of an incandescent electric lamp introduces new uncertainties in photometry by the ordinary rotating lamp method. As this method of photometry is still in

common use it was deemed advisable for the Bureau of Standards to investigate the effect of rotation of the gas-filled lamp on current and candlepower, hoping to derive a practical method of photometry free from the errors due to rotation.

During the investigation extreme care was exercised in the control and measurement of speed of rotation, and the precision photometer was used in making the photometric measurements. It was found that there was for every lamp investigated a speed at which both current and mean horizontal candlepower had the same values, respectively, as when the lamp was stationary, and that this speed had a value which might be conveniently employed in practice, thus suggesting a practical photometric method. It is pointed out, however, that owing to the unequal distribution of bulb discoloration during the life of the gas-filled lamp an integrating sphere should be used in measurements made during life test. G. W. M.

RADIOTELEGRAPHY.—*The effect of imperfect dielectrics in the field of a radiotelegraphic antenna.* J. M. MILLER, Bureau of Standards Scientific Paper No. 269, pp. 129–136. 1916.

It has been shown by the measurements of C. Fischer and L. W. Austin that the curve which represents the variation of the resistance of an antenna with the wave length of the oscilliation has two characteristic features. Starting from the wave length corresponding to the fundamental of the antenna, the resistance of the antenna rapidly decreases with increasing wave length and reaches a minimum. As the wave length is still further increased the resistance rises again, but in a linear manner. The initial decrease in resistance is explained by a decrease in the so-called "radiation resistance." It has been difficult, however, to account for the linear increase which takes place at the longer wave lengths and it is the explanation of this feature that is here considered.

Austin has explained this phenomenon as caused by dielectric absorption and has concluded that it takes place in the ground. Austin's hypothesis with respect to dielectric absorption is confirmed but it is found that the energy loss is not caused by the ground but by the presence of poor dielectrics in the field of the antenna. This conclusion is based upon measurements of the resistance of an experimental antenna constructed so as to eliminate poor dielectrics from its field and at the same time to increase any effects which may be due to the ground. The linear rise in its resistance at very long wave lengths (even at telephone frequencies) was extremely small. It was then found that the

linear increase became considerable when poor dielectrics such as wooden masts, trees, and buildings were in the field and that the resistance of the antenna was also increased at all wave lengths. It was also found that considerable energy loss may be occasioned by running the lead of an antenna into a building. It is most important to design an antenna so as to minimize these sources of energy loss. J. M. M.

GEOLOGY.—*Evaporation of brine from Searles Lake, California.* W. B. HICKS. U. S. Geological Survey Professional Paper No. 98–A. Pp. 8. 1916.

One thousand grams of brine from Searles Lake, California, were evaporated in stages on the steam bath at 78°C. and the deposited crystals were separated from the solution by filtration. The filtrate was cooled to 30°C. and a second fraction of crystals was obtained. Seven such successive stages reduced the brine to about 55 grams and yielded 14 fractions of crystals—7 deposited from the hot solution during evaporation and 7 deposited as the solution was cooled from 78°C. to 30°C. Each fraction of crystals as well as the original brine and the final filtrate was analysed. Most of the sulphate was deposited from hot solution in the first few fractions, and more than 60 per cent of the potassium was deposited as the solution was cooled to 30°C. in the last three fractions. The tabulated results give the percentage composition of the crystals deposited, the percentage of each constituent deposited, and the changes in the composition of the solution during evaporation. W. B. H.

BOTANY.—*New or noteworthy plants from Colombia and Central America—5.* HENRY PITTIER. Contributions from the United States National Herbarium, **18**: 143–171, *pls. 57–80, figs. 88–97.* March 3, 1916.

The present paper is the fifth of a series dealing with new or little known species from South and Central America. Besides descriptions of a few species, either old or here proposed as new and belonging to the Myristicaceae, Anacardiaceae, Hippocrateaceae, Flacourtiaceae, Sapotaceae, Symplocaceae, and Verbenaceae, it contains a full discussion of the genera *Brownea* and *Browneopsis*, based mainly on the author's collections. It includes also a comparison of *Bombax* and *Pachira*, which has resulted in the establishment of a new and intermediate genus, *Bombacopsis*, the two known species of which are natives of Panama and the eastern part of Central America. H. P.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

THE PHILOSOPHICAL SOCIETY OF WASHINGTON

The 773d meeting was held on April 29, 1916, at the Cosmos Club. President BRIGGS in the chair, 43 persons present. The minutes of the 771st and 772d meetings were read in abstract and approved.

Mr. C. W. KANOLT presented a paper entitled *X-ray spectra.* The speaker presented a résumé of the subject, including a review of the state of the theories of the X-rays previous to the use by Laue of a crystal as a diffraction grating, an explanation of the theory of the three-dimensional grating presented by a crystal, and an account of the experimental methods employed and the results obtained. These results give information relative to the nature of the X-rays, permit the determination of the arrangement of the atoms in the simpler crystals, and give some information relative to the structure of the atoms. It was pointed out that it is also possible to determine atomic masses by the measurement of the angles of reflection of X-ray beams from suitable crystals, and the determination of the densities of the crystals. A knowledge of the wave-length of the rays is not required. To obtain by this method an accuracy greater than that of the results that have been obtained by chemical methods it would be necessary to make more accurate measurements of spectra than most of those made hitherto. However, in most of the work that has been done great accuracy has not been required or attempted, and it appears that the methods could be improved sufficiently to give atomic-mass determinations of greater accuracy than most of those that have been made by chemical methods.

The paper was discussed by Messrs. CRITTENDEN, BAUER, and L. J. BRIGGS with reference to the highest atomic numbers and the exceptions found by Moseley in the order of the elements.

Mr. F. E. WRIGHT then presented a communication on *The analysis of crystal structure by X-rays.* In recent years Laue and, especially, W. H. and W. L. Bragg have developed effective methods for using X-rays in the analysis of crystal structure. Laue's method is to send general X-ray radiation through a thin crystal plate and thus to obtain on a photographic plate a diffraction pattern which is an expression of the symmetry relations of the crystal plate. In the Bragg reflection method characteristic X-rays of definite wave-lengths are used and the intensity of the reflected rays is measured by means of an ionization chamber and an electroscope. The crystal plate is mounted in a spectrometer and for a given wave-length, λ, and a fixed distance,

d, between successive layers of atoms parallel with the crystal face, the rays are reflected at maximal intensity at the angle, δ, as defined by the equation $n\lambda = 2d \sin\delta$, in which n is a whole number indicating the order of the spectrum obtained. By thus measuring the distribution and relative intensities of the different order spectra, it is possible to determine the relative atomic spacing and the atomic density of the different planes of the crystal space lattice. Models showing the distribution of the atoms in isometric crystals, such as halite, sylvite, fluorite, diamond, zinc-blende, and pyrite were presented; also drawings illustrating the relations in calcite and dolomite.

Mr. SWANN remarked on the regularity of crystals used as gratings and asked whether measurements made before and after magnetization in substances capable of magnetization to saturation would show different alignment through magnetization of the atoms. Mr. WRIGHT stated that experiments along that line of investigation were proposed.

Informal communications. Mr. E. F. MUELLER exhibited a fused-silicate tube with a transparent quartz window made by the Thermal Syndicate to replace glass and the more expensive quartz tubes used in the sulphur-boiling apparatus. The new type of tube is very satisfactory.

Mr. E. G. FISCHER then exhibited a new signal light designed for use in the triangulation operations of the United States Coast and Geodetic Survey. The oxyacetylene lamp heretofore used is costly and expensive to use because of the bulkiness of the apparatus. The new lamp consists of a tungsten lamp so made and mounted that the filament is practically at the focal point of the parabolic reflecting mirror; it is operated by dry cells. The Bureau of Standards after test reported that the new lamp gives for 2 volts at 2 amperes 250,000 candle power in the beam at 100 feet while the old style of lamp gave only 1500 candle power in the beam at the same distance. It will be possible to make observations by the use of the new light on 20 to 30 per cent of the nights now lost in triangulation work. The relative powers of the two lights were effectively demonstrated by throwing the beam from each on the lantern screen. Mr. BOWIE congratulated the designer upon the development of the new signal.

J. A. FLEMING, *Secretary.*

THE BIOLOGICAL SOCIETY OF WASHINGTON

The 555th regular meeting of the Biological Society of Washington was held in the Assembly Hall of the Cosmos Club Saturday, April 22, 1916; called to order by President HAY at 8.00 p.m. with 24 persons present.

On recommendation of the Council GEORGE H. CLEMENTS, Washington, D. C. was elected to membership.

On recommendation of the Council the following resolutions were read:

WHEREAS, Prof. WELLS W. COOKE, distinguished ornithologist, authority on bird migration, Treasurer of the Biological Society of Washington, and an active member of the Council of the Society, has passed from this life, therefore be it

Resolved: That the Biological Society of Washington deeply regrets the death of one for many years so keenly interested in the affairs of the Society, one who was a peculiarly efficient officer, a wise counselor, and a charming companion, and extends its warmest sympathy to the family of Professor Cooke.

(Signed) N. HOLLISTER
J. W. GIDLEY
ALEX. WETMORE

Under the heading Brief Notes, Dr. HOWARD E. AMES commented upon a question raised at the 553d meeting as to the existence of a South American mammal having the mammae on the dorsal surface of the body. He had ascertained that this condition existed in the coypu (*Myocastor coypu*). Dr. Ames also offered information in regard to another question propounded at the same meeting as to the ability of camels to swim: According to Dr. E. A. Mearns dromedaries used in Abyssinia were able to swim; and in a book by an English Army officer of experience Dr. Ames had found a statement to the effect that camels were powerful swimmers. Comments followed by the chair and by Dr. L. O. HOWARD.

Under the same heading Dr. F. H. BLODGETT discussed the embryology of the duck weed, *Lemna*, and exhibited seeds, remarking that though the plant was common the seeds were seldom found. Dr. Caldwell of Chicago had worked out the development of *Lemna* to the point of fertilization. Studies made by Dr. Blodgett carried the embryology from this point. The talk was illustrated by diagrams. Discussion followed by Mr. W. L. MCATEE.

The first paper of the regular program was by T. H. KEARNEY: *Native plants as indicators of the agricultural value of land.* Mr. Kearney outlined the results of field work carried on with Dr. H. L. SHANTZ in the semiarid regions of the United States west of the 98th meridian. Typical areas were surveyed in Colorado, the Great Basin, and in the Southwest desert region. Detailed surveys defined the dominant types of vegetation and their distribution, and these were correlated with the varying degrees of salinity, moisture content, and other physical properties of the soil. Areas actually under cultivation gave a check as regards productivity. From these studies it is now possible to predict agricultural possibilities by examination of the original types of vegetation in these regions. Typical plant growths and diagrams showing distribution were illustrated by lantern slides.

Mr. Kearney's paper was discussed by Messrs. W. L. MCATEE, WILLIAM PALMER, ALEX. WETMORE, and L. O. HOWARD.

The last paper of the regular program was by Dr. R. W. SHUFELDT: *Comparative study of certain cranial sutures in the primates.* Dr. Shu-

feldt stated that no other single vertebrate structure had so much written about it or was receiving more attention at the present time than the skull in man and the primates in general. This study was begun over two thousand years ago and certain names of bones bestowed by Galen in the second century are still retained. In a series of 6000 human and about 1000 ape skulls in the collections of the U. S. National Museum Dr. Shufeldt found that while the bones of the face exhibited but little variation, in the bones on the lateral aspect of the cranium there were remarkable variations, many of which are not referred to in modern works on anatomy. Frontal, parietal, temporal, alisphenoid, and malar articulations show many variations in sutural lines. These again are varied by the presence or absence of epactal or epipteric bones. By means of lantern slides and diagrams these were illustrated and compared, and the speaker touched upon their value in taxonomy and racial distinction and their pathological significance. Discussion followed by Messrs. L. O. HOWARD, H. E. AMES, and WILLIAM PALMER.

ALEX. WETMORE, *Recording Secretary pro tem.*

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